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Patent Abstract

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PCN 2001-03-15 2001018494/WO-A1 **DIGITAL IMAGING SYSTEM UTILIZING MODULATED BROADBAND LIGHT**

INVENTOR- HULL, Frank, A.

DATE FILED- 2000-09-01
PUBLICATION NUMBER- 2001018494/WO-A1
DOCUMENT TYPE- A1
PUBLICATION DATE- 2001-03-15
3081 Dundee Lane, Mound, MN 55364
INTERNATIONAL PATENT CLASS- G01D00942; *G02B02742
PATENT REFERENCE- 4675702/US-A; 5033814/US-A; 5317446/US-A; 5517347/US-A; 5844588/US-A; 5930027/US-A
PCT APPLICATION NUMBER- 00024192/US
PATENT APPLICATION PRIORITY- 60/152302; 09/484405; 09/505017
PRIORITY COUNTRY CODE- US; US; US
PRIORITY DATE- 1999-09-03; 2000-01-14; 2000-02-16
APPLICANT- CORTRON CORPORATION
PUBLICATION COUNTRY- WO
7855 Ranchers Road, Minneapolis, MN 55432
US
US
FILING LANGUAGE- ENG
DESIGNATED COUNTRY- JP; AT; BE; CH; CY; DE; DK; ES; FI; FR; GB; GR; IE; IT; LU; MC; NL; PT; SE
LANGUAGE- ENG NDN- 263-0296-5720-6

A digital imaging system is disclosed for exposing a light-sensitizable material (46) utilizing a source of non- coherent

light (30). An optical modulator array (40) is optically coupled to receive the non-coherent light from the source (36), and includes a plurality of refractive optical modulators (62). A control circuit (42) is operatively coupled to the optical modulator array (40) to control each of the plurality of refractive optical modulators (62) to create a selected output light pattern. A lens (50) is optically coupled to the modulator array (40) to focus the selected output light pattern onto the light-sensitizable material (46).; L'invention concerne un systeme d'imagerie numerique destine a exposer un materiau rendu sensible a la lumiere (46) au moyen d'une source de lumiere non coherente (30). Un reseau de modulateurs optiques (40), optiquement couple de maniere a recevoir la lumiere non coherente depuis la source lumineuse (36), comprend plusieurs modulateurs optiques de refraction (62). Un circuit de commande (42) est couple de maniere fonctionnelle au reseau de modulateurs optiques (40) de maniere a commander chacun des modulateurs optiques de refraction (62) pour creer un motif selectionne de lumiere emise. Une lentille (50) est couplee optiquement au reseau de modulateurs optiques (40) de maniere a focaliser le motif selectionne de lumiere emise sur le materiau rendu sensible a la lumiere (46).

NO-DESCRIPTORS

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number
WO 01/18494 A1

(51) International Patent Classification[7]: G01D 9/42, G02B 6/04, 26/08, 27/42

(21) International Application Number: PCT/US00/24192

(22) International Filing Date: 1 September 2000 (01.09.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/152,302	3 September 1999 (03.09.1999)	US
09/484,405	14 January 2000 (14.01.2000)	US
09/505,017	16 February 2000 (16.02.2000)	US

(71) Applicant: CORTRON CORPORATION [US/US]; 7855 Ranchers Road, Minneapolis, MN 55432 (US).

(72) Inventor: HULL, Frank, A.; 3081 Dundee Lane, Mound, MN 55364 (US).

(74) Agents: KOENCK, Alan, M. et al.; Kinney & Lange PA, Kinney & Lange Building, 312 South Third Street, Minneapolis, MN 55415-1002 (US).

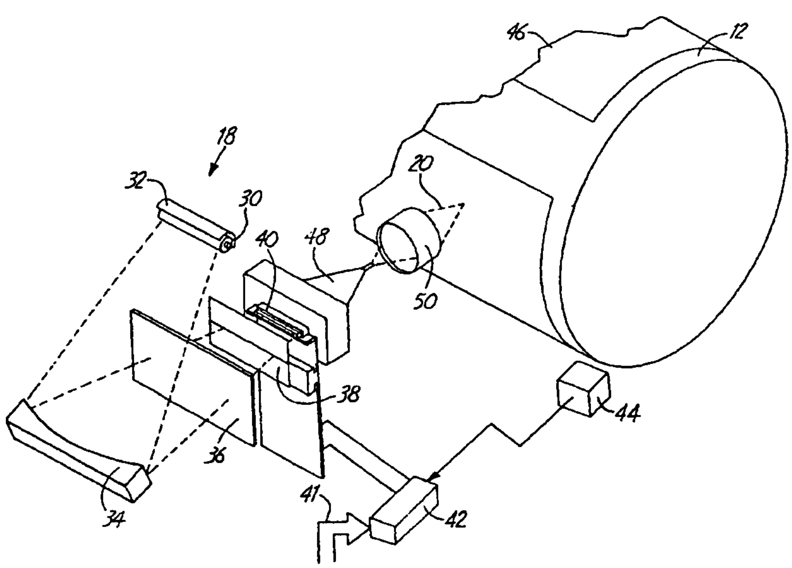
(81) Designated State *(national)*: JP.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DIGITAL IMAGING SYSTEM UTILIZING MODULATED BROADBAND LIGHT



(57) Abstract: A digital imaging system is disclosed for exposing a light-sensitizable material (46) utilizing a source of non-coherent light (30). An optical modulator array (40) is optically coupled to receive the non-coherent light from the source (36), and includes a plurality of refractive optical modulators (62). A control circuit (42) is operatively coupled to the optical modulator array (40) to control each of the plurality of refractive optical modulators (62) to create a selected output light pattern. A lens (50) is optically coupled to the modulator array (40) to focus the selected output light pattern onto the light-sensitizable material (46).

WO 01/18494 A1

DIGITAL IMAGING SYSTEM UTILIZING MODULATED BROADBAND LIGHT

BACKGROUND OF THE INVENTION

The present invention relates to a high resolution digital imaging device employing modulated broadband light to create the individual pixels of the image to be recorded. The invention is particularly useful in the graphic arts industry for exposing a variety of light-sensitizable media such as printing plates, proofing materials, relief plates and the like.

In the graphic arts industry, high resolution images are formed by exposing a light-sensitizable medium such as a printing plate with an appropriate light pattern. Traditionally, the printing plates were covered with a patterned film and exposed by broadband light to create the desired image on the plate. The broadband light was utilized at low energy levels, such that the film intermediary was required to properly expose the plate. More recently, methods that do not utilize film intermediaries have been developed, utilizing digital laser imaging at much higher levels of energy. However, such laser devices are quite expensive due to the relatively high costs of lasers and of the special plates that operate with the laser imaging device, and the laser devices also operate at relatively low speeds. Attempts have also been made to implement printing devices capable of utilizing a broadband light source, with addressing of image pixels being accomplished by reflective spatial light modulators. These devices have proved to be impracticable, in part due to the inability of the reflective spatial light modulators to withstand the required exposure to ultraviolet light, which rapidly breaks down the movable micro-mirrors of the modulators. It would therefore be a significant improvement in the art to provide a durable, high resolution digital imaging system utilizing a less expensive broadband light source that is operable at high speeds with conventional printing plates – such a system is the subject of the present invention.

SUMMARY OF THE INVENTION

The present invention is a digital imaging system for exposing a light-sensitizable material utilizing broadband, non-coherent light at least partially in the ultraviolet spectrum. The non-coherent light is directed into a modulator assembly that includes a plurality or array of individually controllable refractive optical modulators. The refractive optical modulators are individually controlled to either pass the light therethrough and thereby transmit a light beam on to the light-sensitizable material and create a "light" pixel, or to refract the light for subsequent absorption and/or dissipation of the light so as to create a "dark" pixel on the light-sensitizable material. A selected output light pattern is therefore created by the arrangement of "light" and "dark" pixels. In an exemplary embodiment, a fiber assembly is coupled to the optical modulator array for transmitting the light passed through the refractive optical modulators to the light-sensitizable medium and for absorbing and dissipating the light refracted by the optical modulators. A lens is provided to focus the selected output light pattern onto the light-sensitizable material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a typical digital imaging system for utilizing an imager according to an embodiment of the present invention.

FIG. 2 is a diagram of the imager head optics utilized with a digital imaging system according to an embodiment of the present invention.

FIG. 3 is a diagram illustrating the operation of the modulator employed by an embodiment of the present invention in more detail.

DETAILED DESCRIPTION

FIG. 1 is a block diagram showing the components of a typical high resolution broadband light digital imaging system 10 for utilizing an imager according to the present invention. Digital imaging

system 10 operates in a manner known in the art to form high resolution images by exposing a light-sensitizable medium such as a printing plate with an appropriate light pattern. Rotating drum 12 is driven by drum drive 14, imager assembly 16 includes imager 18 focusing light 20 onto drum 12 in a controlled pattern, and computer 22 controls operations of imager assembly 16 and drum drive 14. In accordance with the present invention, imager 18 shown in FIG. 1 employs a novel broadband light modulating system that improves the overall performance of the digital imaging system, with the details of imager 18 being shown in more detail in FIG. 2.

FIG. 2 is a diagram of imager 18 of the high resolution digital imaging system of the present invention. Broadband non-coherent light source 30, such as an ultraviolet plasma capillary tube, is seated in ellipsoid cylindrical section reflector 32 or a similar apparatus for focusing non-coherent light in a selected direction. The light is focused onto cylindrical reflector 34, which is coated to reflect light only in the wavelengths of interest, such as in the 360-400 nanometer (nm) range. Light reflected by cylindrical reflector 34 is convergent in two planes, and is directed through polarizer 36, which passes only light waves that are aligned with the polarization angle of polarizer 36. The polarized light impinges on aperture 38, which serves to trim the polarized light to match the input dimensions of modulator array 40, with the non-coherent light preferably being shaped to slightly over-flood the aperture. Thus, polarized light passes through aperture 38 as a beam having a width equal to the length of modulator array 40 and having a height equal to the total height of the modulators in modulator array 40, and the divergence of the light is low, preferably less than about 1.5 degrees. The light is thereby apportioned into the plurality of individually controllable modulators contained in modulator array 40.

Digital information 41 in the form of a binary image file is utilized by modulator driving circuit 42 to control modulator array 40 and thereby create a selected output light pattern for imaging. The position

of drum 12 is provided to modulator driving circuit 42 by encoder 44 in order to synchronize the release of data to modulator array 40 with the position of drum 12, so that the modulation pattern is correlated to the imaging row on light-sensitive medium 46 mounted to drum 12. Output fiber assembly 48 is connected to receive and further transmit the light output from modulator array 40. Each modulator in modulator array 40 refracts or bends the light according to the control signal applied thereto by modulator driving circuit 42. For a first state of the modulator control signal, the light is refracted by an individual modulator at such an angle that the light is not transmitted through fiber assembly 48, but instead passes through the fiber wall and is absorbed and dissipated by the cladding and/or jacket of the fiber therein. For a second state of the modulator control signal, the light is merely passed through the individual modulator, with no more than negligible refraction, and is emitted from an end of fiber assembly 48. In an alternate embodiment, where the divergence of the light is sufficiently consistent, such that the fibers are not required to integrate the power distribution and divergence angles of the light on the light-sensitizable medium, fiber assembly 48 may be omitted and a stop plate employed instead, with each modulator being configured so that light is either passed from the modulator or refracted to impinge upon the stop plate. In this manner, light beams are switched "on" (passed through the modulator) or "off" (refracted by the modulator so as to be absorbed and/or dissipated at the output fiber) to create a modulation pattern for imaging on printing plate 46 mounted on drum 12. Final focusing lens 50 is provided to focus the modulated light output from fiber assembly 48 onto light-sensitizable medium 46 for proper exposure thereof. In an exemplary embodiment, the optical fibers of fiber assembly 48 taper from a 0.5 millimeter (mm) square area input aperture adjacent each modulator of modulator array 40 to a 0.020 mm square area output aperture (corresponding to the pixel resolution of the imaging system) to be focused onto light-sensitizable medium 46 mounted on recording drum 12 by focusing lens 50. Focusing lens 50

may be of the relay type, the telecentric type, or the anamorphic type, depending on the imaging requirements as is known in the art. By rotating drum 12 a full revolution, and advancing modulator array 40 horizontally to cover the entire width of medium 46 (with at least one revolution of drum 12 for each position of modulator array 40), the entire expanse of medium 46 can be imaged quickly, efficiently, and with high resolution. In one embodiment, the horizontal advancement of modulator array 40 can be controlled such that there is partial overlap between horizontal positions, so that the intensity of the output from modulator array 40 can be reduced while still achieving full exposure of medium 46.

The optical switches provided in modulator array 40 utilized by the present invention are illustrated in more detail in FIG. 3. Light 60 enters each modulator 62 after passing through adjustable aperture 38. Aperture 38 serves the purpose of limiting the light to only the active area inside modulator 62 and allows over-flooding of the light, thus preventing pointing and falloff errors inherent when trying to fill the input with a matched beam size. Light 60 is slightly divergent at approximately a 1.5 degree half-angle entering modulator 62. Modulator 62 is a refractive electro-optic modulator constructed of a high index material lowering the divergence to 0.68 degrees whilst in modulator 62. Active area 64 of modulator 62 is constructed such that all light passing through the input will remain within its active area 64. Application of a voltage potential across modulator 62 causes the light beam to be refracted or bent as shown by beam 66. In an exemplary embodiment, modulator 62 is a broad cell electro-optic refractive modulator manufactured by Applied Electro-Optics Corporation of Pittsburgh, PA. Coupled to the modulator is tapered optical fiber 68 of the same size as active area 64 of the modulator 62. Light passing through modulator 62 in its normal state (no more than negligible refraction) is coupled to fiber 68 and exits at the opposite end reduced in size by the taper of fiber 68. The fiber taper has two functions: first; it reduces the size of the output

beam in accord with the taper, and second, it reduces the fiber's input Numerical Aperture (NA) by the ratio of the taper. In an exemplary embodiment, the fiber is configured with a 12-to-1 taper having an input NA of 0.018 and an output NA of 0.22, which causes the fiber not to transmit light entering beyond a 1.0 degree divergence angle. Other taper arrangements may be employed with similar effects on the NA of the fiber to obtain desired transmittance characteristics of the fiber for acceptable divergence angles of light.

Light that is refracted by modulator 62 in its active (refractive) state exceeds the critical angle that fiber 68 will transmit (i.e. reflect off of the fiber wall within the fiber), such as the 1.0 degree angle of the exemplary embodiment having a 12-to-1 taper, and therefore is not passed to the fiber output, as dictated by the Total Internal Reflectance (TIR) function of fiber 68. Instead, the refracted light strikes the wall of the fiber at an angle greater than the critical angle so that the light passes through the wall and is absorbed and dissipated by the cladding and/or outer jacket of the fiber. Tapered fiber 68 produces an output whose optical nature is achromatic, i.e. the light does not induce any focal displacement that is dependent upon wavelength of light. A lens-based optical reduction system at the output of modulator 62 would be cost prohibitive to make achromatic at the high demagnification ratios employed with the present invention. In addition, the divergence angle of light output from the fibers will not exceed the intrinsic NA capability of the fiber. This results in control of beam spread even though the system is operating at high demagnification.

An exemplary design of modulator 62 is an optical switch realized by a prism-type refractive structure, in which prism-shaped regions with different indices of refraction are created with an applied voltage via the electro-optic effect, such as a lithium nobate glass structure operating by inversion of ferroelectric domains and serving as an optical grating. Alternatively, a gradient-type refractive device may be utilized, where a nonuniform electric field distribution is created in the

modulator crystal and induces a similar index distribution which bends the light as it propagates through the modulator. The optical switch causes light to bend as it passes therethrough, with the bending being predictable based only on the voltage applied to the glass and the length of the glass. The refractive optical switches are broad cell devices, operable to refract the entire light input received by the switch. By utilizing an optical switch in the manner of the present invention rather than a mechanically vibrating device such as an acousto-optic modulator having a piezoelectric vibrator, for example, the imaging system is essentially power-unlimited. As a result, beams with high enough power to effectively expose the printing plate mounted on the recording drum (typical plates require at least approximately 0.18 Watts per beam, based on a specification of 0.3 Joules per square centimeter at an exposing rate of 30 square centimeters per second) can be achieved without concern for the capacity of the optical switching components in the modulator. In an exemplary embodiment, a line of 96 pixels, defined by a stack of 96 modulators, may be exposed at a sufficient power level by utilizing a relatively inexpensive broadband light source, such as a 5000 Watt plasma capillary light source having a 500 Watt ultraviolet output, although it should be understood that light sources with higher output power may also be used with the present invention due to the power-unlimited nature of the modulator switches.

The present invention therefore is a high resolution digital imaging system utilizing non-coherent light to expose a pre-sensitized medium such as a printing plate, particularly for use in the graphic arts industry, and provides several advantages over prior art systems such as lower cost, higher speed, and improved durability and reliability. The system is capable of operating with conventional printing plates, which is advantageous because of the lower cost associated therewith and the acceptance in the industry of such printing plates as compared to thermal printing plates for use with laser imaging systems. The system is able to achieve high resolution with outstanding beam quality and

clarity, while utilizing a broadband non-coherent light source and a modulator assembly, output fiber assembly and focusing lens for defining individual pixels of the digital image and focusing the beams on the printing plate mounted on a recording drum. The modulator assembly utilizes a plurality of optical switches that are power-unlimited, enabling a high powered broadband light source to be used and sufficient power to be contained in each output beam to properly expose the printing plate with the desired pattern, controlled by appropriate control signals applied to the modulator to operate the optical switches according to a predetermined graphical image stored in a computer. In addition, because the optical switches employ refractive optical modulators having no moving parts, they are able to withstand the relatively high levels of ultraviolet light delivered by the system. The coupling optics have a fill factor of approximately 100%, such that in an exemplary embodiment a 5000 Watt plasma capillary light source providing 500 Watts of ultraviolet power is able to achieve about 20 Watts of power at the output of the system, or about 0.2 Watts per beam, which is sufficient to successfully expose the printing plate mounted on the recording drum. It should be understood that higher-powered light sources may also be used to increase the output power of the system, since the modulators are essentially power-unlimited devices at all spectra. The present invention also exposes the printing plate with square pixels, which is advantageous due to the uniformity of power achievable with such a pixel shape. In an exemplary application, the present invention utilizing an inexpensive 5000 Watt plasma capillary light source is able to expose a conventional 30 inch by 40 inch printing plate in approximately 4.3 minutes, which is comparable performance to much more expensive laser imaging systems.

It should be understood that although the present invention has been described with reference to a standard rotating drum imaging system, the principles of the present invention are equally applicable to other types of imaging systems, such as systems that linearly translate

the pre-sensitized medium and systems that employ a reciprocating, scanning imaging head to traverse and expose the medium. Other potential applications of the invention in a number of imaging applications will be apparent to those skilled in the art, and are within the province of the present invention.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

CLAIMS:

1. A method of imaging a light-sensitizable material, the method comprising:

providing non-coherent light at least partially in an ultraviolet spectrum;

directing the non-coherent light into a modulator array;

apportioning the non-coherent light into a plurality of individually controllable modulators in the modulator array;

selectively refracting the non-coherent light in each of the plurality of individually controllable modulators in a first non-refracted state and a second refracted state so as to create a selected output light pattern; and

focusing the selected output light pattern from the plurality of individually controllable modulators onto the light-sensitizable material.

2. The method of claim 1, wherein selectively refracting the non-coherent light in each of the plurality of individually controllable modulators comprises:

coupling a fiber assembly to the plurality of individually controllable modulators, the fiber assembly including a plurality of optical fibers corresponding to the plurality of individually controllable modulators; and

applying a control signal to each individually controllable modulator to select one of the first non-refracted state and the second refracted state, wherein light is transmitted through respective ones of the plurality of optical fibers when corresponding modulators are in the first non-refracted state and light is absorbed and dissipated by at least one of

a cladding and jacket of respective ones of the plurality of optical fibers when corresponding modulators are in the second refracted state.

3. The method of claim 2, wherein each of the plurality of optical fibers has an input aperture adjacent an output of a corresponding one of the plurality of individually controllable modulators and has an output aperture tapered to a smaller dimension than the input aperture.

4. The method of claim 3, wherein each of the plurality of optical fibers is tapered to only transmit light having a divergence angle no greater than about 1.0 degrees.

5. The method of claim 1, wherein focusing the selected output light pattern from the plurality of individually controllable modulators onto the light-sensitizable material comprises:

mounting the light-sensitizable material on a rotating recording drum; and

horizontally moving the plurality of individually controllable modulators after each complete revolution of the recording drum.

6. The method of claim 5, wherein an extent of horizontal movement of the plurality of individually controllable modulators is such that the plurality of modulators overlap their previous position.

7. A digital imaging system for exposing a light-sensitizable material, the system comprising:

a source of high intensity non-coherent light at least partially in an ultraviolet spectrum;

an array of refractive optical modulators coupled to receive the non-coherent light from the source;

a control circuit operatively coupled to the array of refractive optical modulators to create a selected output light pattern of transmitted and non-transmitted light beams from the array of refractive

optical modulators with a power level of about 0.2 Watts per beam; and

a lens optically coupled to the array of refractive optical modulators for focusing the selected output light pattern onto the light-sensitizable material.

8. The digital imaging system of claim 7, wherein the source of high intensity non-coherent light provides an ultraviolet power output of at least 500 Watts.

9. The digital imaging system of claim 7, wherein each modulator in the array of refractive optical modulators is operable to refract light in a first state and to pass light in a second state, wherein the selection of the first state and the second state in the array of modulators creates the selected output light pattern.

10. The digital imaging system of claim 9, further comprising a fiber assembly coupled between the array of refractive optical modulators and the lens for selectively transmitting the selected output light pattern.

11. The digital imaging system of claim 10, wherein the fiber assembly comprises an array of individually tapered optical fibers each coupled to corresponding modulators of the array of refractive optical modulators, each of the tapered optical fibers including at least one of a cladding and an outer jacket and being configured to absorb and dissipate refracted light in the first state of the refractive optical modulators and to transmit passed light in the second state of the refractive optical modulators.

12. The digital imaging system of claim 11, wherein the array of individually tapered optical fibers each transmits only light entering the fiber at an angle of less than about 1.0 degrees.

13. The digital imaging system of claim 7, wherein the refractive optical modulators are prism-type refractive devices.

14. The digital imaging system of claim 13, wherein the prism-type refractive devices operate by inversion of ferroelectric domains.

15. The digital imaging system of claim 7, wherein the refractive optical modulators are gradient-type refractive devices.

16. The digital imaging system of claim 7, wherein the light-sensitizable material is mounted on a rotating recording drum.

17. The digital imaging system of claim 16, wherein the array of refractive optical modulators is moved horizontally after each complete revolution of the recording drum.

18. The system of claim 17, wherein an extent of horizontal movement of the array of refractive optical modulators is such that the array of refractive optical modulators overlaps its previous position.

19. A digital imaging system for exposing a light-sensitizable material, the system comprising:

a source of high intensity non-coherent light at least partially in an ultraviolet spectrum;

an array of refractive optical modulators coupled to receive the non-coherent light from the source;

a control circuit operatively coupled to the array of refractive optical modulators to create a selected output light pattern of refracted and non-refracted light beams from the array of refractive optical modulators;

an array of tapered optical fibers each coupled to corresponding modulators of the array of refractive optical modulators, each of the tapered optical fibers including at least one of a cladding and an outer jacket and being configured to absorb and dissipate refracted light beams and to transmit non-refracted light beams in the selected output light pattern; and

a lens optically coupled to the array of tapered optical fibers for focusing the non-refracted light beams onto the light-sensitizable material.

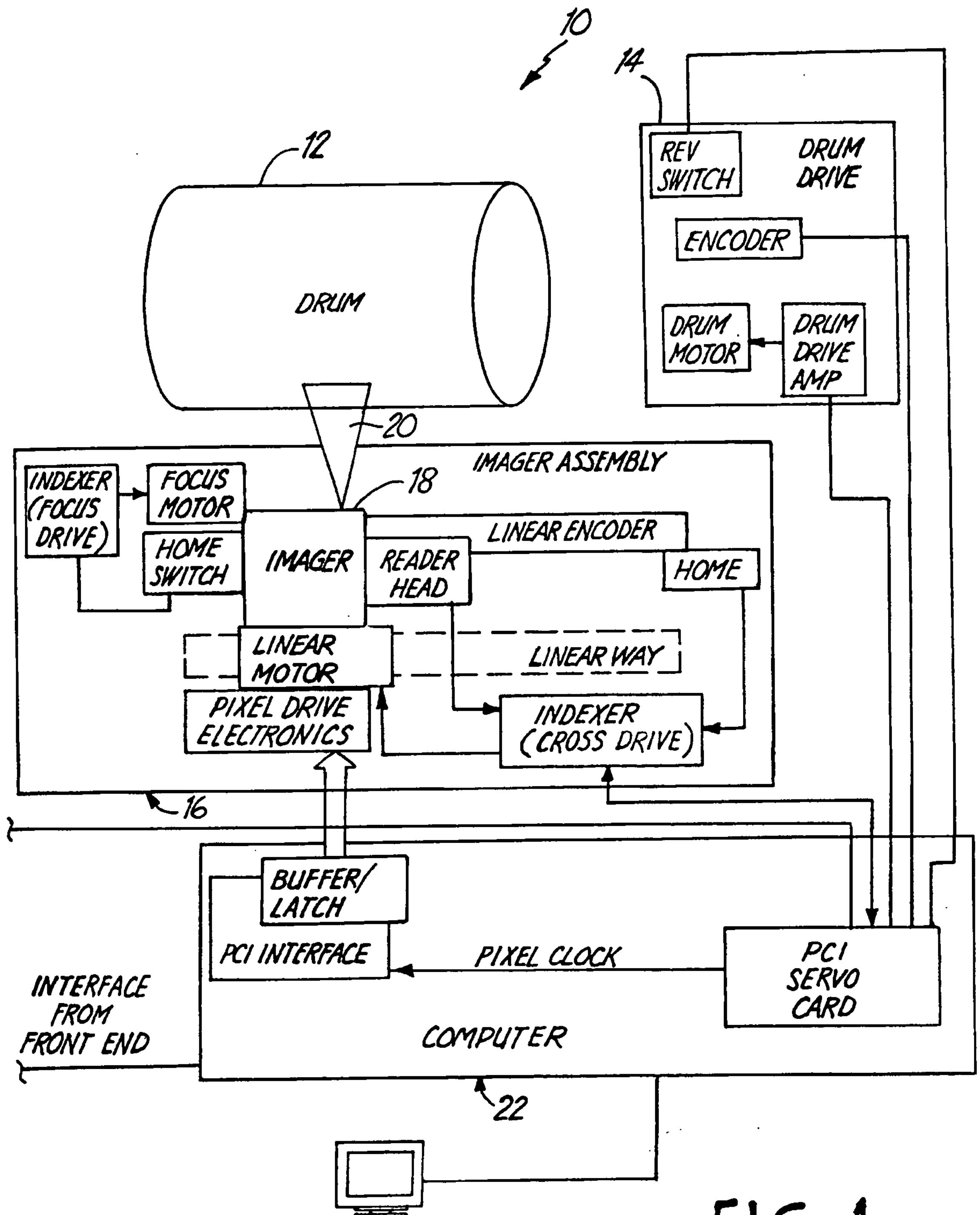

10
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FIG. 1

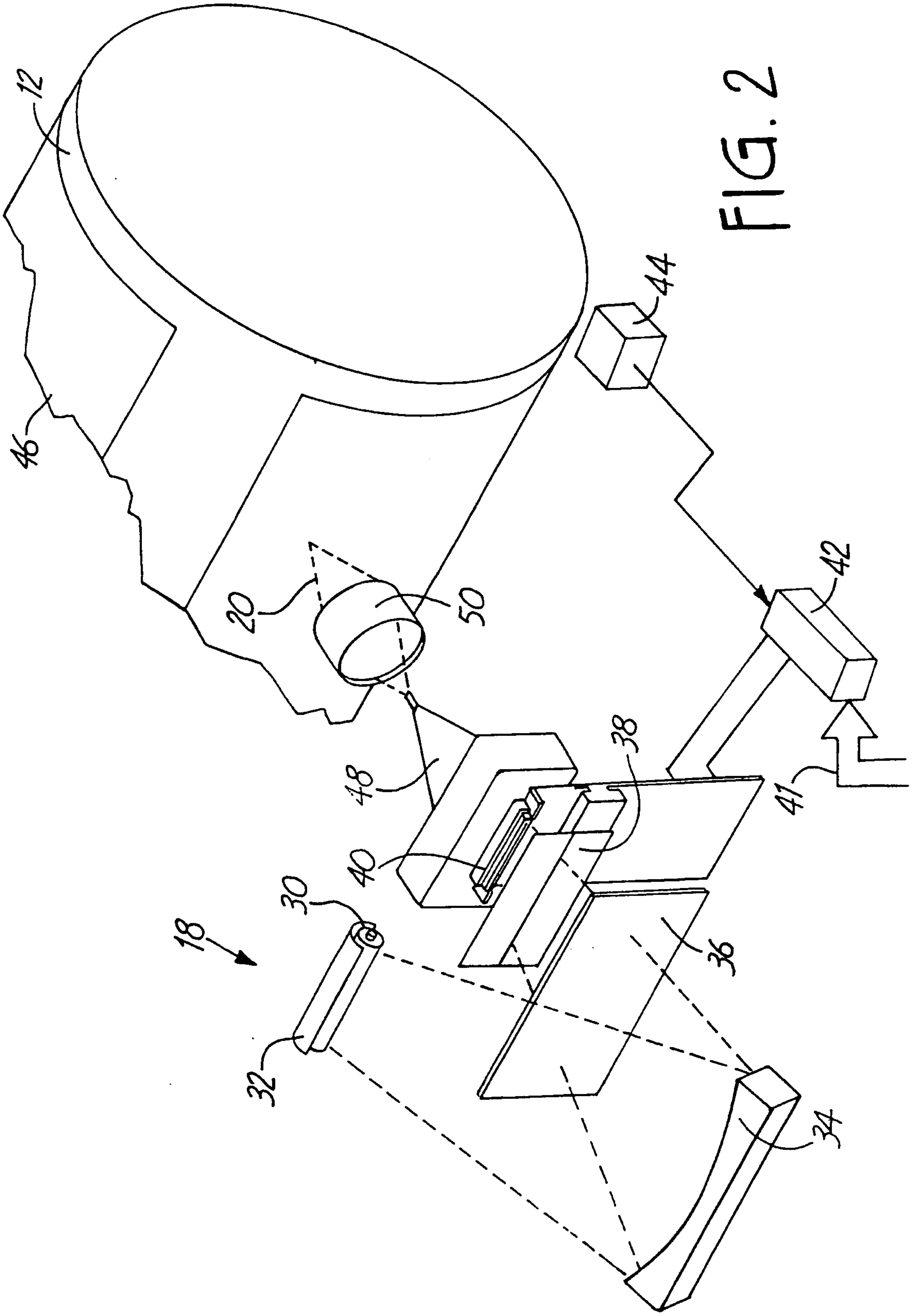

FIG. 2

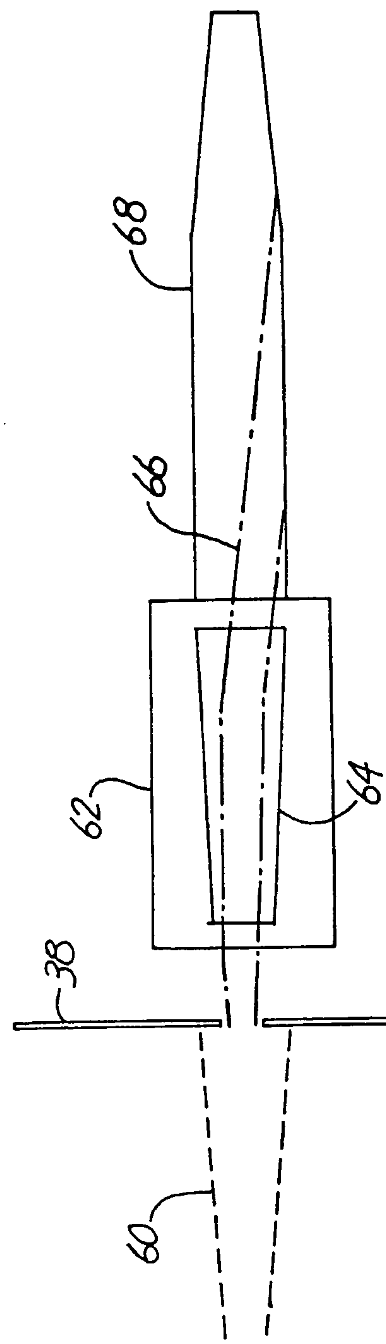

FIG.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/24192

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G01D 9/42; G02B 6/04, 26/08, 27/42
US CL :347/233, 239, 241, 243, 255, 256, 259, 135; 385/16; 349/5; 359/224, 259
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 347/233, 239, 241, 243, 255, 256, 259, 135; 385/16, 32, 43, 115, 116, 119, 120, 121; 349/5; 359/224, 259, 237, 245, 315

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,844,588 A (ANDERSON) 01 December 1998 (01.12.1998), col. 4, lines 23-59 and col. 5, lines 44-52.	1, 7-8
X	US 5,517,347 A (SAMPSELL) 14 May 1996 (14.05.1996), col. 2, lines 23-67 and col. 5, lines 1-10.	2-3, 10-11, 16, 19
X	US 5,033,814 A (BROWN et al) 23 July 1991 (23.07.1991), col. 3, lines 6-61 and col. 6, lines 38-51.	9, 13-15
X	US 5,317,446 A (MIR et al) 31 May 1994 (31.05.1994), col. 2, lines 49-61.	14
X	US 4,675,702 A (GERBER) 23 June 1987 (23.06.1987), figs. 1 and 2.	5-6, 17-18

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 OCTOBER 2000	16 NOV 2000

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Renee Preston

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,930,027 A (MENTZER et al) 27 July 1999 (27.07.1999), figs. 3A-C and 4.	4, 12